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It was voted that the amendment be enacted.

The following gentlemen were elected members of the Academy: —

G. Kirchhoff, of Berlin, to be a Foreign Honorary Member in Class I., Section 3, in place of the late Thomas Graham.

Kaulbach, of Munich, to be a Foreign Honorary Member in Class III., Section 4, in place of the late Overbeck.

Henry Carey Lea, of Philadelphia, to be an Associate Fellow in Class III., Section 3.

Professor E. J. Cutler, of Cambridge, to be a Resident Fellow in Class III., Section 2.

Professor E. J. Young, of Cambridge, to be a Resident Fellow in Class III., Section 2.

Professor C. C. Langdell, of Cambridge, to be a Resident Fellow in Class III., Section 1.

Six hundred and twenty-sixth Meeting.

December 13, 1870. — MONTHLY MEETING.

The PRESIDENT in the chair.

Professor J. D. Whitney read the first part of a communication on the fossil remains of man found in California.

Professor N. S. Shaler called attention to the fact that the circumstances connected with the occurrence of these remains beneath Table Mountain resembled, in a striking way, those of similar remains found near Le Puy in Haute-Loire, France.

Professor J. D. Whitney called attention to the discovery, by Mr. Clarence King, of glaciers in the northern slope of Mt. Shasta.

Mr. E. N. Horsford gave an account of the system of hydraulic mining in California.

Six hundred and twenty-seventh Meeting.

January 9, 1871. — MONTHLY MEETING.

The PRESIDENT in the chair.

The President read a letter from Professor Kirchhoff, of

Berlin, acknowledging his election as Foreign Honorary Member.

The President announced the death of Professor E. J. Cutler, Resident Fellow of the Academy.

Professor J. D. Whitney continued the reading of his paper on the remains of pre-historic man in California, left unfinished at the last meeting.

The following communication on the Tides, by Lieutenant Roumiantzoff, was read.

In the note "sur la theorie des marées" (*Comptes Rendus*, May 16, 1870) I defined the phenomena of tidal vibrations. The view I take on the subject is simply a development of the general idea expressed by Laplace in his *Mécanique Céleste.* Laplace in fact established that: —

a. The phenomena of tides consist in the movements of fluid;

b. The infinitely small motion of particles of water is possible only on the surface of their level;

c. The fluctuation of level on the coast is secondary in respect of oceanic motion.

At this time the physical description of the phenomena was very insufficient, and the local circumstances on which the tides depended were unknown; consequently Laplace could not follow out the true principles of his theory, and arrived in his final results at an assumption of a certain proportionality between the phenomena of tides and the disturbing forces. (*Vide* Laplace, *Mécanique Céleste*, Tome V. Chapitre XIII.)

At the present time many of the peculiarities of the tides have been shown by observers, and the principles which were wanting have been mentioned in the remarkable works on "Tides" by the Astronomer-Royal, Mr. Airy, Dr. Whewell, and others. These investigations have caused the fundamental idea in Laplace's theory to be lost sight of; so that until the present time the phenomena of tidal motion have been examined as the disturbance of the form of waters in the ocean under the influence of attracting bodies. At sea-stations we observe not the form of the free surface of waters surrounding the solid globe, but the result of the small horizontal vibrations of the particles of the ocean waters; and thus the investigation of the equations of the surfaces of the ocean level does not include the theory of tides. Such an explanation is in visible contradiction with the remarkable theory of "waves," by Mr. Airy, the works of Whewell, and others; but I will immediately show that it would be highly important to apply the solutions given in these works to the explanation given in my former notice. There I particularly endeavored to explain the origin of tidal currents of great rate, and then I said, in short, that we should have to investigate the propagation of tidal currents in bays. Mr. Whewell, in his numerous works, having acquainted us with the geography of the phenomena, and shown many details, as well as many empirical laws of the tides, avails himself also of the idea of "cotidal lines" in explaining the peculiarities of the tides. As is well known, the cotidal lines are curves drawn through the points of simultaneous high waters; their position on the map is associated with the idea of the propagation of tidal motion. The phenomena of tides in the ocean being fully determined by the theory, it is evidently impossible to draw the cotidal lines across the ocean, in the same way as the question is impossible, — "Whether high or low water will occur at the transit of an attracting body." It would be highly important to make use of the theory of cotidal lines to explain the propagation of tidal currents, in which case the cotidal lines will be the direct expression of the physical law. The cotidal lines connecting the points, at which the greatest velocity of tidal currents is being simultaneously observed, are necessary for the study of tidal phenomena in large bays (as e. g. White Sea and German Ocean). Notwithstanding this, the explanation of the phenomena is still very difficult when they occur in rivers, and where the tide rises gradually; whereas the superficial currents are very irregular and slack. In these cases, starting from the theory developed by Mr. Airy in his work "Tides and Waves," we arrive at the laws of the phenomena. If, in fact, the pressure of the ocean in its progress meets with great resistance in the system of waters in a quiescent state, or running in the opposite direction, then the propagation of this pressure will be observed as taking place in the form of waves (positive).

The general description of the phenomena of tides was given by me in the more simple case when the bay is immediately connected with the ocean. The observations of tidal currents made by many eminent American, English, and French observers, and also the full investigation of tidal currents in the White Sea by the Russian hydrographer, Risnecke, have been taken by me as authorities. From the foregoing remarks we can infer how complicated the phenomena will be in many cases; in each instance of this kind a separate physical description will be indispensable, as the local circumstances are sometimes very different. The most simple case for the investigation of the laws of tidal currents is afforded by observations made on shoals at a great distance from the coast. Thus observations on the shoals of the German oceans, of the Sooloo Sea, and others, do not show the existence of any noticeable rise of level. Let us suppose a shoal in the middle of the ocean, the depth of the ocean to be 20,000 feet, and 20 feet on the shoal, then the velocity of waters on the shoal could not exceed the rate of the ocean motion more than one thousand times. In any case, the velocity of the current on this shoal will not be great, as the ocean motion is too slow; besides, the velocity of tidal currents increases gradually from nothing, and if the shoal is of small superficial dimensions, then the resistance to the progress of tidal motion will be insignificant, and observations will not show any rise of level. I will here add an explanation why tides are not strong at the islands of the open ocean, but attain great dimensions in bays and narrows along the coast of the continent. In the former case, the lesser mass of the ocean waters helps to communicate a progressive motion to the particles of water; whereas, in the latter case, all the mass of the ocean presses on the coast of the continent, and the running waters being reflected from the promontories and straight shore convey their *vis viva* to the waters of the bays and narrows which indent the shore of the continent.

I subjoin the following remarks to the conclusions made by me in the first note:—

1. The Astronomer-Royal, Mr. Airy, in his works on the tides, more than once points to the inadequacy of all the theories of the tides (see e. g. Airy, "Tides and Waves," Section II., No. 14); thus in the first conclusion I explain the results given by Mr. Airy.

2. The time and the magnitude of the greatest velocity of tidal currents are opposed by me to the generally admitted rule of investigating the laws of times and heights of high water. According to the theory of tidal motion, the velocity of the current may be given by the function of the disturbing forces, whereas the rise of level will be a very complex function of currents, which only can be expressed by an empirical formula, because many of the local circumstances cannot be analytically stated.

3. The law of the revolving direction of tidal currents (from E. round by N. in north lat. and from E. round by S. in south lat.) is

confirmed by all observations made in points open to the ocean. In contracted estuaries and along the shore the currents follow the shore line. In some points of a complicated and large bay a change in the reverse direction is sometimes observed, as these points are reached by the currents after many reflections from the shore.

4. The relation of the rise of the tide to the velocity of the flow solely depends upon local circumstances. If the shore extends perpendicularly to the direction of the flow at its greatest rate, then high water occurs soon after the time of maximum of velocity. In bays stretching considerably inland, when the velocity is small and the rise depends on the mass of water remaining in, the time of high water occurs considerably later than the time of greatest velocity of the current from the ocean. This delay becomes an essential element in the theory of tides, for it determines the time and height of high water, and upon it depends the retard of the spring and neap tides after the days of syzygy and quadrature.

5. The first part of the *establishment* is drawn from the theory; the second, with the magnitude of the greatest velocity of flow, determines the influence of local circumstances.

6. The absence of full uniformity in the mean level immediately proves that the height of the lunisolar tides is not equal to the algebraical addition of the lunar and solar tides (one of the evident inferences of theory of tidal motion). In fact, Mr. Airy deduced from the observations "that the mean level is higher in the large tides than in the small ones." ("Tides and Waves," p. 374. . . . . "The mean level at Sheerness is higher in spring tide than in the neap tide by seven inches nearly." . . . . And I inferred from this that the lunisolar tide is greater than the addition of solar and lunar tides at Sheerness by about fourteen inches.) This inequality might be considerable; but the various resistances to tidal motion on the coast reduce the large tides far more than the small tides. Proceeding from the observations made in Ireland, Mr. Airy alluded to the difference of the mean height of the sea round the island. The definition of the normal level on the coast is immediately deduced from my explanation of the phenomena of tides. In some points of a complicated large bay, the level of low water at spring tide may be higher than the ocean level (in case of a constant movement of the waters); but the level in the bay during a quiescent state of waters (as observed at low water) will never fall lower than the ocean level. The small motion of the

particles of the ocean waters from the shore will be followed by a similarly small fluctuation of the level along the coast.

The observations of the rise of the tide give us the result of the effect of all the causes without the possibility of distinguishing the power of each of them separately. In fact, the elevation of the level corresponds to each periodical current from the ocean; thus, to explain some inequalities of the heights of tides, we must consider the causes from which the periodical currents may proceed. For instance, the diurnal inequality of heights is observed in all morning and evening tides, which undergoes a periodical change according to the season of the year. But, on the other hand, the difference between the heating of the waters by the sun along the shore (where the diurnal amplitudes in the temperature are very considerable) and in the ocean will cause the periodical currents. Certain other inequalities in the heights of tides will also proceed from the periodical and accidental variations in the direction and rate of the constant local currents. The power of the wind to drive the waters into the bays increases the height of the level. The anomalies in the phenomena of tides are explained by the interferences of the currents, and by the streams caused by the difference of the level in the nearest points.

Six hundred and twenty-eighth Meeting.

January 25, 1871. — STATED MEETING.

The PRESIDENT in the chair.

There being no quorum for the transaction of business, the matters which should have been acted upon at this meeting were postponed.

The President announced the death of Professor William Chauvenet, Associate Fellow of the Academy.

Professor N. S. Shaler made a communication on the Geology of the region about Richmond, Va. He claimed that the sienite ridge which occurs at that point was of later elevation than the rest of the Appalachian Ridge, which it clearly resembled in many important regards; furthermore, that the salient angle of Cape Hatteras was caused by the elevation of this ridge. Mr. Shaler also claimed that the Cincinnati axis of